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USE ATTAINABILITY ANALYSIS FOR UPPER SANDIA CANYON

DRAFT FINAL

Prepared for

Los Alamos National Laboratory

For submittal to

New Mexico Environment Department

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Acronyms

4T3	water temperature not to be exceeded for 4 or more consecutive hours in a 24-hour period on more than 3 consecutive days
6T3	water temperature not to be exceeded for 6 or more consecutive hours in a 24-hour period on more than 3 consecutive days
ARIMA	autoregressive integrated moving average
ATEMP	average July air temperature
AU	assessment unit
AWTC	air-water temperature correlation
CFR	Code of Federal Regulations
DO	dissolved oxygen
GCS	grade control structure
HMP	habitat management plan
IR	integrated report
LANL	Los Alamos National Laboratory
LANL MET	Los Alamos National Laboratory meteorological monitoring network
MWAT	maximum weekly average (water) temperature
NPDES	National Pollutant Discharge Elimination System
NMAC	New Mexico Administrative Code
NMDGF	New Mexico Department of Game and Fish
NMED	New Mexico Environment Department
PI	prediction intervals
PRISM	Parameter-elevation Relationships of Independent Slopes Model
RMSE	root mean square error
SSTEMP	stream segment temperature
SWQB	NMED Surface Water Quality Bureau
TMAX	maximum water temperature
Triad	Triad National Security
UAA	use attainability analysis
USFWS	US Fish and Wildlife Service

WQCC	Water Quality Control Commission
WQS	water quality standards

1 Introduction

This document presents a use attainability analysis (UAA) for the perennial segment of Upper Sandia Canyon, which is located within the Los Alamos National Laboratory (LANL) property near Los Alamos, New Mexico.¹ This UAA is consistent with 20.6.4.15 New Mexico Administrative Code (NMAC) (New Mexico Environment Department [NMED] 2011c), which describes the perennial segment as “Sandia Canyon from Sigma Canyon upstream to LANL [National Pollutant Discharge Elimination System] NPDES outfall 001.” The perennial segment’s designated uses are coldwater aquatic life, livestock watering, wildlife habitat, and secondary contact.

40 Code of Federal Regulations (CFR) § 131.10(g) permits a state to remove a designated use that is not an existing use (as defined in 40 CFR §131.3), if a UAA demonstrates that naturally occurring pollutant concentrations prevent the attainment of the use or if physical conditions related to the natural features of the water body preclude the attainment of the aquatic life protection use. This UAA considers whether natural physical conditions in Upper Sandia Canyon, specifically air and/or water temperatures, prevent the designated aquatic life use water temperature limits (i.e., coldwater) from being attained in the perennial segment. The weight of evidence presented in this UAA supports the conclusion that, based on air-water temperature modeling and instream thermograph data, the coolwater aquatic life designated use is currently the attainable use. Accordingly, it is recommended that the coolwater aquatic life designated use replace the coldwater aquatic life designated use in the Upper Sandia Canyon assessment unit (AU).

¹ Within this document, the terms “LANL” and “the Laboratory” are used to distinguish between the organization and the physical area on the Pajarito Plateau controlled and operated by LANL, respectively.

2 Site Description and History

Upper Sandia Canyon is one of several segments described by 20.6.4.126 NMAC (NMED 2011c). It is a perennial reach originating within the Laboratory and includes one AU, “NM-9000.A_47, from NPDES outfall 001 to Sigma Canyon” (hereinafter referred to as the Upper Sandia Canyon AU) (Figure 1). Outfall 001, located at LANL’s Technical Area (TA) 3, discharges an average of 154,000 gallons per day (and a maximum of 333,000 gallons per day), creating a continuously flowing waterbody in Upper Sandia Canyon (EPA 2020). Most of the water comes from the co-generating power and steam plant, which generates heat, electricity, and steam used for LANL activities.² While Outfall 001 is the primary source of water flow to the Upper Sandia Canyon AU, two other NPDES outfalls, Outfall 027 and Outfall 199, also discharge much smaller volumes of effluent to the AU.³ Both outfalls discharge cooling tower effluents.

² <https://www.lanl.gov/environment/protection/compliance/industrial-permit/outfall-map.php>

³ Outfalls 027 and 199 (shown on Figure 1) are also known as Outfalls 03A027 and 03A199.

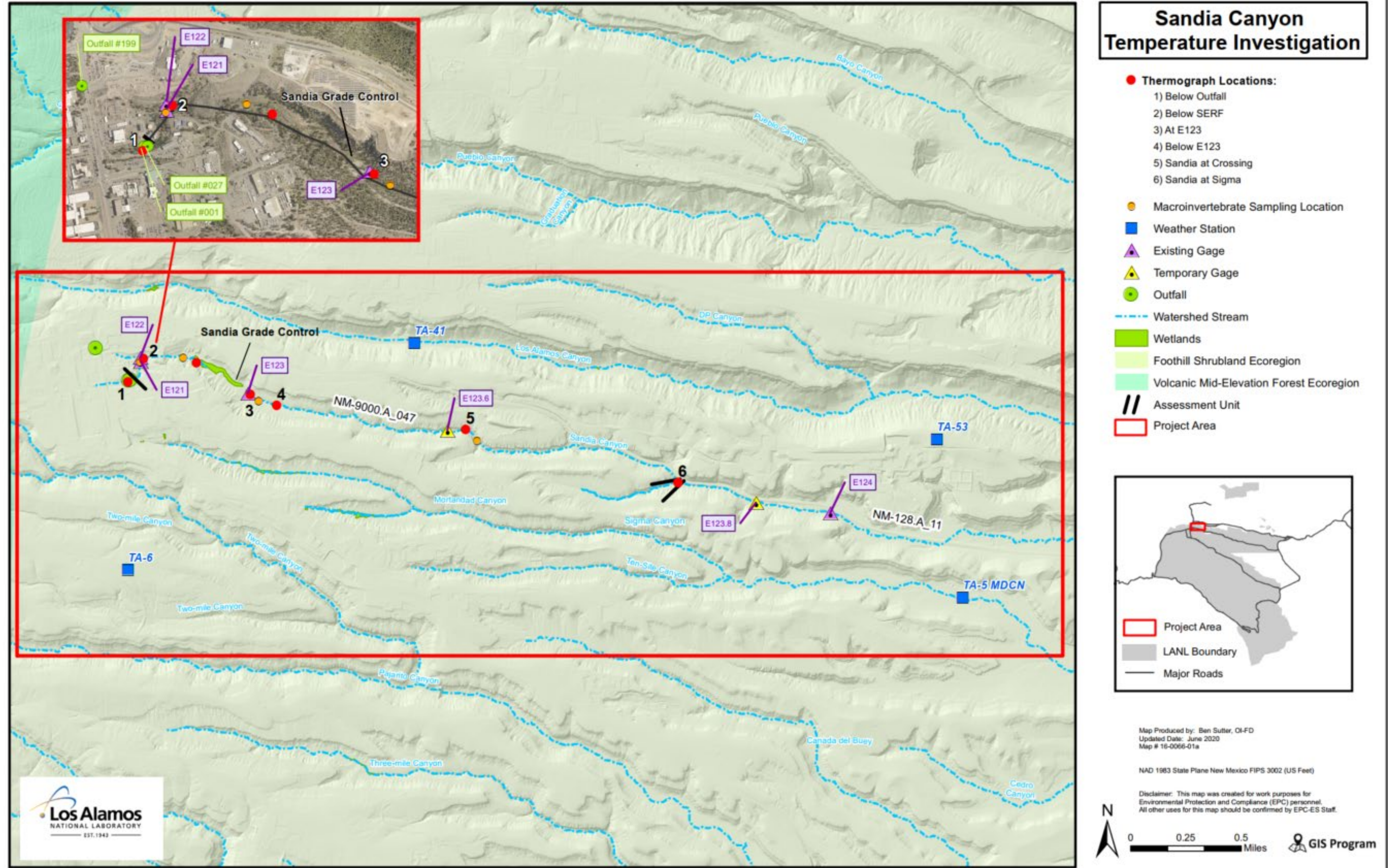


Figure 1. Upper Sandia Canyon AU

Upper Sandia Canyon is effluent dependent, meaning that it would not be perennial without effluent inputs. Discharge into Sandia Canyon began in the 1950s (LANL 2008) and now supports a 3.65-acre wetland (Stanek et al. 2020) near the upper end of the Upper Sandia Canyon AU, just downstream of the outfalls. Wetland sediments are underlain by Bandelier Tuff, upon which alluvial groundwater is perched. Past investigations have shown little evidence of significant infiltration beneath the wetland (LANL 2013). For example, in a water balance study conducted between 2007 and 2008 (LANL 2008), only about 2% of the surface water entering the wetland infiltrated the underlying bedrock. Past comparisons of surface water chemistry results from above and below the wetland have demonstrated that baseflow has a short residence time, and that there is little exchange between surface water and groundwater within the wetland (Iacona 2015). Installation of a grade control structure (GCS) in 2013 reduced the rate of erosion at the downstream end of the wetland and created an impermeable barrier to subsurface flow, such that alluvial groundwater must now resurface before exiting the wetland. Given the impermeable nature of this barrier and the largely impermeable tuff underlying the wetland, the wetland can conceptually be thought of like a bathtub that effectively holds water; excess water overflows from the wetland at the GCS. Annual evaluation of baseflow rates has confirmed this description, as rates entering and exiting the wetland have been similar (N3B 2019).

LANL (2008) determined the water budget for sources of flow and loss throughout the canyon. The study concluded that the perennial segment of Upper Sandia Canyon is a net-neutral or net-losing stream from the wetland to the end of the Upper Sandia Canyon AU (Table 1); in other words, the amount of water in the stream is stable or decreases over its length as a result of evaporation, infiltration, or surface water loss to alluvial groundwater. Flow in alluvial well gages correlated with changes in outfall flow, as well as with precipitation events. Daily temperature swings in alluvial groundwater also correlated with air temperature fluctuations. These patterns indicate that the alluvial storage is small, and that the alluvium is recharged by Sandia Canyon surface water.

Table 1. Approximate surface water budget in Upper Sandia Canyon from July 2007 to June 2008

Process and Area ^a	Estimated Gain or Loss (acre ft/yr)	Percent of Total
Discharge from outfalls	389	75
Runoff above E123	130	25
Evapotranspiration in wetland	-18	-3
Infiltration beneath wetland	-12	-2
Infiltration between wetland and D123.6	0	0
Surface water loss between D123.6 and D123.8	-119	-23
Surface water loss between 123.8 and E124	-334	-64

Process and Area ^a	Estimated Gain or Loss (acre ft/yr)	Percent of Total
Surface water loss between E124 and E125	-36	-7

Source: LANL (2008)

^a E123, E124, and E125 are permanent surface water gage stations in Upper Sandia Canyon. D123.6 and D123.8 were temporary gage stations for the water balance study (LANL 2008).

In 2005, the New Mexico Water Quality Control Commission (WQCC) adopted the Upper Sandia Canyon AU as a classified water of the state, designating a use of coldwater aquatic life and a segment-specific temperature criterion of 24°C. The decision to adopt the segment-specific temperature criterion was based on a 2002 US Fish and Wildlife Service (USFWS) study (Lusk et al. 2002), which found that water temperatures within the Upper Sandia Canyon AU exceeded 20°C but not the maximum summer temperature for the survival of brook trout (24°C).⁴ Time-averaged peak temperatures were not considered in that study, because time-averaged criteria had not yet been adopted by the WQCC as part of the New Mexico water quality standards (WQS).

In 2010, as part of a revision of the New Mexico WQS, the WQCC replaced the eliminated and replaced the Upper Sandia Canyon AU's site-specific criterion of 24°C with the general coldwater aquatic life designated use temperature criterion (also 24°C) from 20.6.4.900.H NMAC (NMED 2011c). In a subsequent rulemaking proceeding, the WQCC adopted the 6T3 criterion⁵ of 20°C and made it applicable to the statewide coldwater designated use (Table 2). Attainability of the 6T3 criterion in the Upper Sandia Canyon AU has not been previously analyzed.

⁴ Sandia Canyon drains to the Rio Grande. The downstream end of the perennial reach is located approximately 8 miles upstream and 1,300 vertical feet above the Rio Grande. Aquatic life surveys of Sandia Canyon have found no fish (LANL 2017).

⁵ Water temperature not to be exceeded for 6 or more consecutive hours in a 24-hour period on more than 3 consecutive days.

Table 2. New Mexico temperature criteria for aquatic life designated uses

Aquatic Life Designated Use	Maximum Temperature (°C)^a	6T3 (°C)	4T3 (°C)
High-quality coldwater	23	--	20
Coldwater	24	20	--
Marginal coldwater ^b	29	25 ^c	--
Coolwater	29	--	--
Warmwater	32.2	--	--
Marginal warmwater ^b	32.2	--	--
Limited ^b	no default established	--	--

Source: 20.6.4.900.H NMAC (NMED 2011c)

^a Unless segment-specific maximum temperature criteria exist in 20.6.4.97 through 20.6.4.899 NMAC; default 4T3 and 6T3 are not applicable in these cases per 20.6.4.900.H(1)(2)(3) (NMED 2011c).

^b Marginal and limited designated uses apply only to naturally low-flowing streams; therefore, these uses would not apply to the perennial reach of Upper Sandia Canyon.

^c With the exception of 20.6.4.114 NMAC, which contains a segment-specific 6T3 of 22°C (NMED 2011c).

4T3 – water temperature not to be exceeded for 4 or more consecutive hours in a 24-hour period on more than 3 consecutive days

6T3 – water temperature not to be exceeded for 6 or more consecutive hours in a 24-hour period on more than 3 consecutive days

NMAC – New Mexico Administrative Code

Temperature is one of the most common causes of water quality impairment in New Mexico. The Upper Sandia Canyon AU is listed as impaired due to temperature exceedances, as discussed in the NMED’s 2018–2020 integrated report (IR) (NMED 2018), and is assigned an IR Category of “5B,” indicating the need for review of the WQS.

3 Ecoregion Setting

The Laboratory was built upon the Pajarito Plateau, which EPA (2019) characterizes as southern Rocky Mountain foothill shrub lands, volcanic mid-elevation forests, and north-central New Mexico valleys and mesas. The Pajarito Plateau slopes downward to the east-southeast, covering approximately 15 miles from the base of the Jemez Mountains (7,800 ft elevation) to the Rio Grande (5,400 ft elevation). Habitat on the Pajarito Plateau consists of irregular rolling hills and finger mesas composed primarily of soft, erodible Bandelier Tuff.

The Upper Sandia Canyon AU falls within ecoregion 21d, “Northwestern Forested Mountains-Western Cordillera-Southern Rockies-Foothill Woodlands and Shrubs” (EPA et al. 2006; EPA 2019). Ecoregion 21d, which extends from Wyoming through Colorado and into northern New Mexico, is characteristically dry Rocky Mountain habitat dominated by pinyon juniper and oak woodland forests at 6,000 to 8,500 ft of elevation (EPA et al. 2006). The Upper Sandia AU is located within a transitional zone between mountainous and xeric regions, and air and water temperatures reflect this transition. Section 9 provides information illustrating that water temperatures warm along the transition from the mountainous to transitional to xeric ecoregions.

4 Air-Water Temperature Correlation Model

Air temperature and water temperature are highly correlated (NMED 2011a), so air temperature data can be used to understand what water temperatures can be attained in the Upper Sandia Canyon AU. The NMED Surface Water Quality Bureau (SWQB) air-water temperature correlation (AWTC) model has been used in past UAAs (e.g., NMED 2017, 2011b) to estimate water temperature statistics and substantiate which aquatic life designated uses are attainable. This UAA applies the same line of evidence, as described in this section.

4.1 DESCRIPTION OF THE AWTC

The statistics needed to determine attainable uses for the Upper Sandia Canyon AU were the 6T3 and TMAX.⁶ These statistics were estimated using the AWTC equations (Equations 1 and 2)⁷ and then compared to New Mexico temperature criteria (Table 2) to estimate which aquatic life designated uses are likely attainable in the Upper Sandia Canyon AU.

$$6T3 = 1.0346 \times ATEMP + 1.3029 \quad \text{Equation 1}$$

Where:

ATEMP = average July air temperature in the Upper Sandia Canyon AU

$$TMAX = 1.0661 \times ATEMP + 4.9547 \quad \text{Equation 2}$$

Where:

ATEMP = average July air temperature in the Upper Sandia Canyon AU

4.2 AWTC MODEL APPLICATION TO SITE

Two datasets were used to generate independent ATEMP estimates:

- ◆ Near-surface air temperature data from the LANL meteorological monitoring network (LANL MET) (LANS 2019)

⁶ The 4T3 criterion (water temperature not to be exceeded for 4 or more consecutive hours in a 24-hour period on more than 3 consecutive days) only applies to the high-quality coldwater designated use (Table 2). The purpose of this UAA is to show that the coldwater designated use cannot be attained because of elevated water and air temperatures, so the 4T3 and high-quality coldwater designated use were generally not considered herein. An exception is found in Table 5.

⁷ Equations 1 and 2 are the final equations reported by NMED (2011a), which assumed an approximate equivalency between ATEMP and the maximum weekly average (water) temperature (MWAT); the MWAT value was used to generate the slopes and intercepts in Equations 1 and 2, but then ATEMP was substituted for MWAT. This is relevant to the discussion in Section 10, which revisits the AWTC.

- ◆ Parameter-elevation Relationships of Independent Slopes Model (PRISM) (NACSE 2019) daily mean air temperature data

The Upper Sandia Canyon AU comprises two PRISM grid cells, referred to hereinafter as Upper Sandia AU-west⁸ and Upper Sandia AU-east.⁹ Data for the two PRISM cells, along with the July average temperatures estimated from the PRISM data, are provided in Appendix A, Tables A1 and A2.

Two LANL MET stations, TA-6 and TA-53, are in close proximity to the Upper Sandia Canyon AU. TA-6 is located near the head of Twomile Canyon, approximately 1 mile south of and at approximately the same elevation as Outfall 001 (Figure 1). TA-53 is located on the narrow mesa between Sandia Canyon and Los Alamos Canyon, approximately 1 mile east of the lower extent of the Upper Sandia Canyon AU, at an elevation of 6,990 ft. Daily minimum and maximum temperatures from the thermometer closest to the ground (height = 1.2 m) at each station were recorded from July 2014 through July 2018. These data were used to estimate a daily mean air temperature (as the midpoint between the daily minimum and the daily maximum)¹⁰ and an average July air temperature (Appendix A, Tables A3 and A4).

Table 3 presents the average July air temperatures for Upper Sandia Canyon (based on two PRISM cells and two LANL MET stations) from 2014 to 2018, the associated AWTC-predicted 6T3s, TMAXs, and the designated uses that could be attained at those levels. The attainable uses were determined by comparing the 6T3 and TMAX values to temperature criteria (Table 2) and summarized in Table 3 by year and among years. The warmest attainable use among the sources of air temperature data and among years was selected as the projected attainable use (per the air temperature line of evidence). Based on the summary provided in Table 3 and air temperature thresholds specified by NMED (2011a), the current coldwater aquatic life use is unattainable. This modeling exercise found the coolwater and warmwater aquatic life uses to have been attainable in the Upper Sandia Canyon AU between 2014 and 2018. With the exception of 2016 and 2018, modeling approaches more frequently predicted that coolwater was attainable than was warmwater; in 2018, the two uses were equally likely based on modeling. Altogether, these results suggest that the coolwater use should be attainable in cooler years (e.g., 2014 and 2015) and warmwater should be attainable in warmer years (e.g., 2016). Overall, the warmest attainable use throughout the monitoring period was warmwater.

⁸ Centroid for PRISM cell is at latitude 35.8755, longitude -106.3181; elevation 7,582 ft.

⁹ Centroid for PRISM cell is at latitude 35.8694, longitude -106.3073; elevation 7,149 ft.

¹⁰ The use of a midpoint in place of the mean assumes that the temporal trend in temperatures for each day was sinusoidal and approximately symmetrical about the mean.

Table 3. Use attainability evaluation for Upper Sandia Canyon AU based on TMAX from four estimators of average July air temperature over the period 2014–2018

Year	Average July Air Temperature (°C)				6T3 (°C)				TMAX (°C)				Projected Attainable Use by Year by Metric				Projected Attainable Use by Year
	PRISM		LANL MET		PRISM		LANL MET		PRISM		LANL MET		PRISM		LANL MET		
	Upper Sandia AU-West	Upper Sandia AU-East	TA-6	TA-53	Upper Sandia AU-West	Upper Sandia AU-East	TA-6	TA-53	Upper Sandia AU-West	Upper Sandia AU-East	TA-6	TA-53	Upper Sandia AU-West	Upper Sandia AU-East	TA-6	TA-53	
2014	20.7	21.6	20	21.5	22.7	23.7	22.0	23.5	27.0	28.0	26.3	27.9	coolwater	coolwater	coolwater	coolwater	coolwater
2015	19.7	20.5	19.4	19.6	21.7	22.5	21.4	21.6	26.0	26.8	25.6	25.9	coolwater	coolwater	coolwater	coolwater	coolwater
2016	24	25.2	22.9	24.6	26.1	27.4	25.0	26.8	30.5	31.8	29.4	31.2	warmwater	warmwater	warmwater	warmwater	warmwater
2017	21.3	22.3	21.4	23	23.3	24.4	23.4	25.1	27.7	28.7	27.8	29.5	coolwater	coolwater	coolwater	warmwater	warmwater
2018	22.2	22.6	21.6	23.3	24.3	24.7	23.7	25.4	28.6	29.0	28.0	29.8	coolwater	warmwater	coolwater	warmwater	warmwater
Projected Attainable Use =																	Warmwater

^a Daily maximum air temperatures were not available for July 2015 at TA-53 (except for July 15). Instead, daily maximum temperatures were calculated using 15-minute interval air temperature data from the thermometer 1.2 m above the ground (or from the thermometer 11.5 m above the ground, when data from the lower thermometer were not available).

6T3 – water temperature not to be exceeded for 6 or more consecutive hours in a 24-hour period on more than 3 consecutive days

AU – Assessment Unit

LANL MET – Los Alamos National Laboratory meteorological monitoring network

PRISM – Parameter-evaluation Relationships of Independent Slopes Model

TA – Technical Area

TMAX – maximum water temperature

4.3 EVALUATION OF LANL MET AND PRISM MODEL DATA

A statistical modeling approach was used to determine whether 2014 to 2018 July air temperatures from LANL MET towers and PRISM were consistent with expectations based on previous years. If 2014 to 2018 air temperatures were “warm outliers,” then that would call into question the representativeness of water temperature data for the same time period.¹¹

Autoregressive integrated moving average (ARIMA) models were developed using the R statistical program (R Core Team 2017) and either LANL MET or PRISM data. Each ARIMA model was then used to forecast time-series data for 2014 to 2018. Prediction intervals (PIs) were generated around forecast results, and 2014 to 2018 temperature data were compared to PIs around the ARIMA forecast estimates. Temperature data that fell outside the PIs were considered to be extreme. Conversely, values within the PIs were considered to be within reasonable expectation, given historical trends.

In total, four ARIMA models were developed (Figure 2), two based on historical PRISM data and two based on historical LANL MET data:

- ◆ PRISM - Upper Sandia AU-east data from 1983 to 2013
- ◆ PRISM - Upper Sandia AU-west data from 1983 to 2013
- ◆ LANL MET data from tower TA-6 from 1990 to 2013
- ◆ LANL MET data from tower TA-53 from 1992 to 2013¹²

¹¹ Additional uncertainty associated with the air temperature data is discussed in Sections 6 and 10.

¹² Historical data for TA-6 and TA-53 only went as far back as 1990 and 1992, respectively.

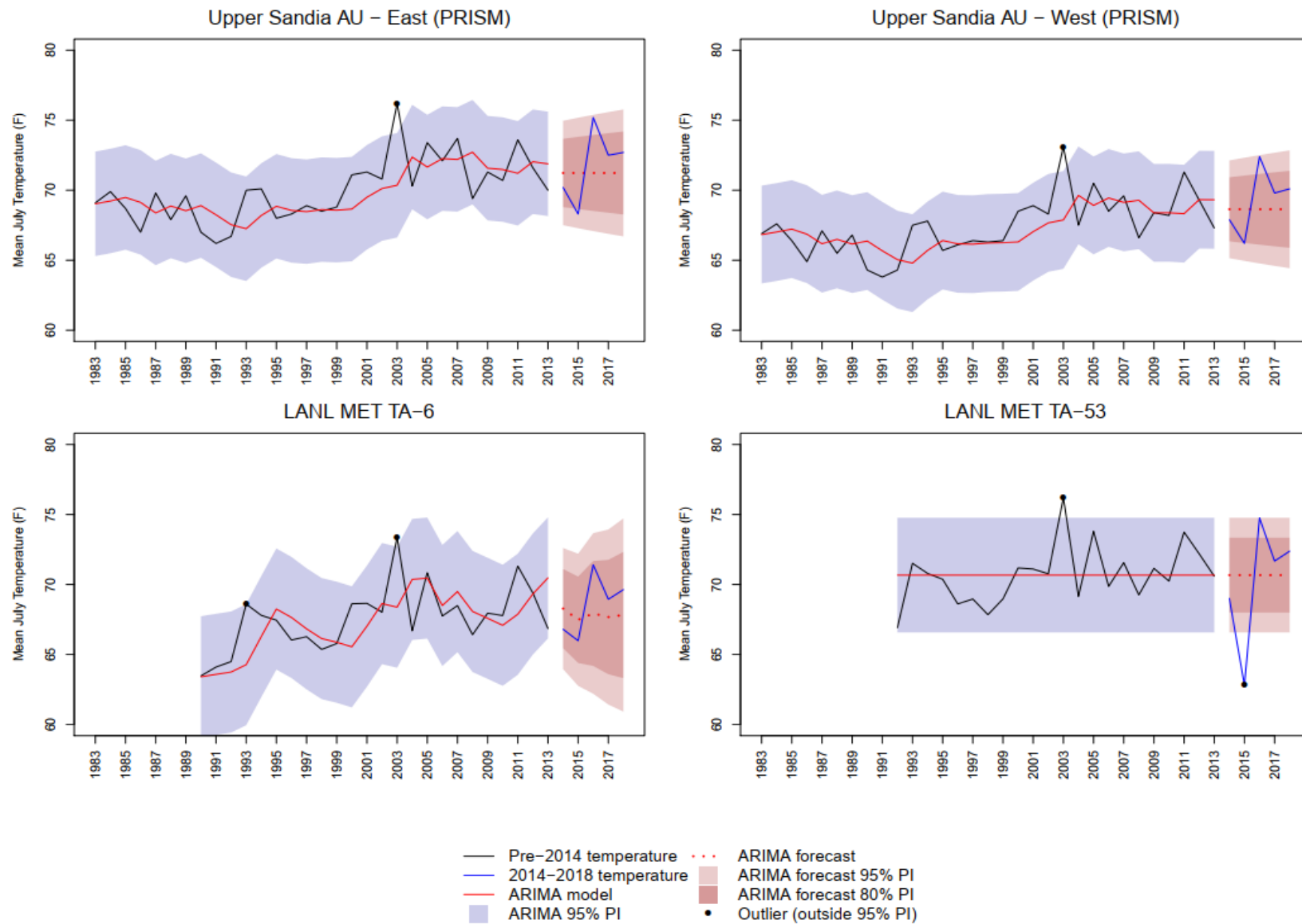


Figure 2. ARIMA model result for PRISM and LANL MET average July temperatures

Based on all four ARIMA forecasts, mean July temperatures from 2014 to 2018 were as expected (i.e., within the 95% PI). Following this logic, the water temperatures predicted by the AWTC model are not warmer than expected. One exception, which can be seen in Figure 2, results from 2015 data measured at TA-53; these data were colder than expected by ARIMA.¹³ Overall, however, ARIMA-predicted 2014 to 2018 water temperatures should be considered representative of attainable water temperatures in “typical” years (given expected air temperatures).

¹³ The TA-53 model is somewhat uncertain because no trend over time was discernible, resulting in a fixed mean temperature and relatively narrow PI. This differs from the other three ARIMA models.

5 Stream Segment Temperature Model

In accordance with LANL (2020), the stream segment temperature (SSTEMP) model was used to simulate temperatures in the Upper Sandia Canyon AU and estimate effects resulting from potential changes in alluvial groundwater inflow and outflow. The model was developed to predict minimum, mean, and maximum daily stream temperatures based on watershed geometry, hydrology, and meteorology (Bartholow 2004). Four different modeling scenarios were evaluated using 2007 and 2017 data from several stream gages (Table 4). These time periods were selected because they had continuous streamflow data.

Table 4. SSTEMP estimates

Model Scenario	SSTEMP Model Temperature Estimate (°C)			No. of Days with Continuous Flow Data	Estimated Use Attained ^a
	Minimum ^b	Mean ^b	Maximum ^b		
E121/E122 to E123	13.91	20.37	26.87	31 (July 2017)	coolwater
E123 to E123.6	15.74	22.04	28.37	8 (July 23 to 30, 2007)	coolwater
E123 to E123.8	16.72	22.55	28.38	8 (July 23 to 30, 2007)	coolwater
E123.6 to E123.8	16.85	22.98	29.11	8 (July 23 to 30, 2007)	warmwater

^a The estimated use is based on the predicted maximum temperature compared to TMAX criteria for aquatic life designated uses (Table 2). Minimum and mean estimates are not comparable to criteria, thus no comparison of SSTEMP estimates can be made to 6T3 or 4T3 criteria.

^b Value was estimated on a daily basis and average among all modeling days.

4T3 – water temperature not to be exceeded for 4 or more consecutive hours in a 24-hour period on more than 3 consecutive days

6T3 – water temperature not to be exceeded for 6 or more consecutive hours in a 24-hour period on more than 3 consecutive days

SSTEMP – stream segment temperature

TMAX – maximum water temperature

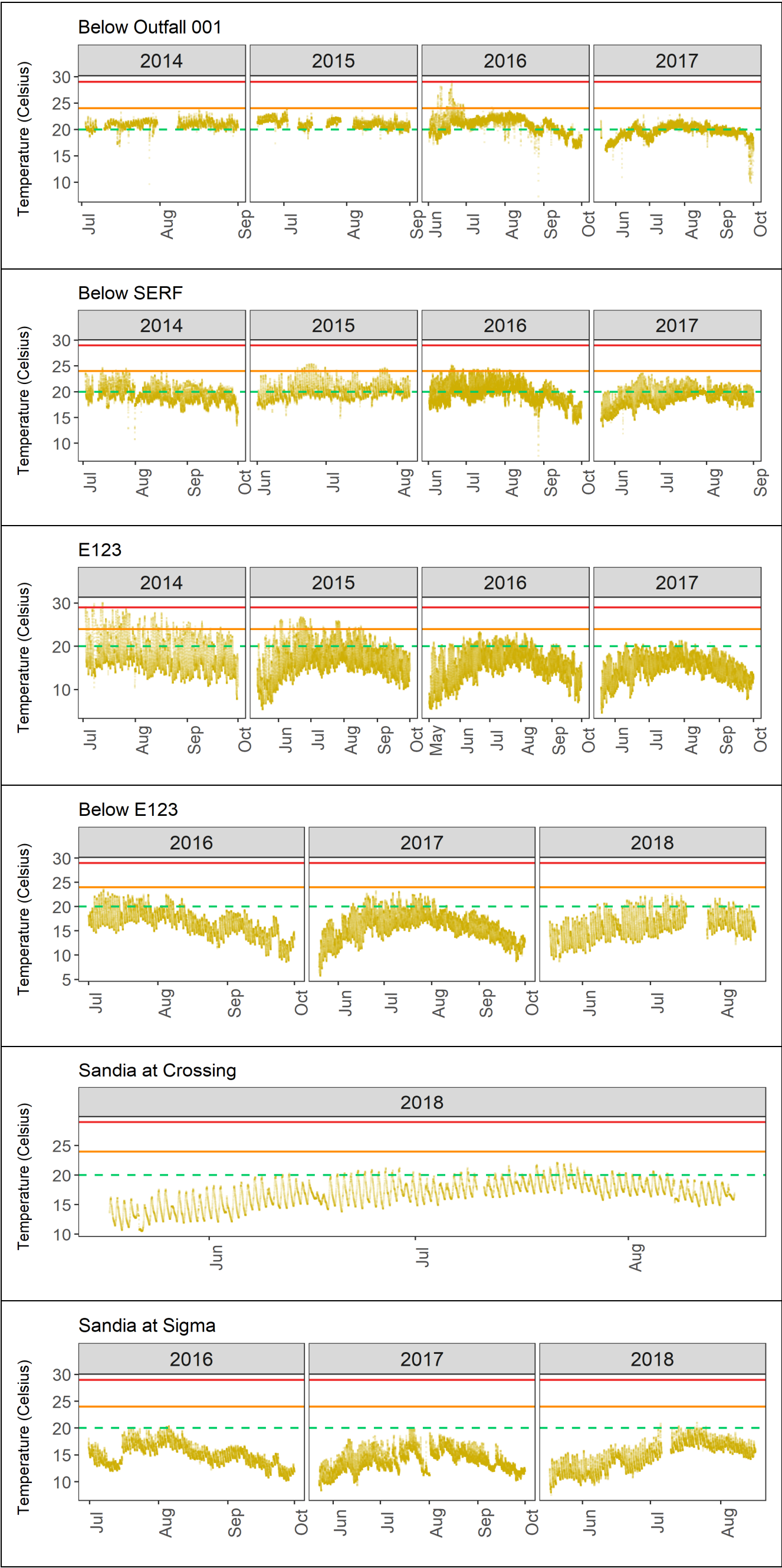
The temperatures summarized in Table 4 were derived under a variety of flow conditions. The purpose of evaluating multiple conditions was to determine if inflow from the surrounding alluvium influences stream temperature predictions. The sensitivity analysis generated by SSTEMP for each scenario indicated that mean air temperature had the greatest influence over estimated mean stream temperatures, while inflow temperature, relative humidity, wind speed, and possible sun had lesser (but still significant) influences over predicted mean temperatures. The SSTEMP modeling results support the AWTC modeling results described in Section 4 and provide another line of evidence that coldwater aquatic life criteria in the Upper Sandia Canyon AU are not attainable. The results in Table 4 also suggest that a coolwater use designation for the Upper Sandia Canyon AU is generally appropriate.

6 Water Temperature Data Evaluation

This section provides a discussion of available water temperature measurements from the Upper Sandia Canyon AU (Section 6.1), including temperatures from Outfall 001 (Section 6.2), which is the dominant source of water in the AU. All water temperature data were obtained directly from Los Alamos National Security/Triad National Security (Triad) in Microsoft® Excel files (LA-UR-18-28589 and LA-UR-18-30926). The unattainability of the coldwater aquatic life designated use with respect to air temperatures (and predicted water temperatures) is discussed in detail in Sections 4 and 5, and this section provides strong evidence for the unattainability of the coldwater use based on measured water temperatures.

6.1 UPPER SANDIA CANYON THERMOGRAPH WATER TEMPERATURES

Between 2014 and 2017, LANL deployed five thermographs in the Upper Sandia Canyon AU in order to monitor water temperatures directly. In 2018, a sixth thermograph was deployed at the Sandia at Crossing location. LANL's thermographs became exposed to the air on several occasions due to storm events or low flow conditions, leading to very high false temperature readings (up to 61°C). Triad identified those periods when the thermographs became exposed, and Windward Environmental LLC removed those data from consideration (e.g., when calculating 6T3 values and determining exceedances of criteria). Figure 3 shows the remaining 2014 to 2018 thermograph data, comparing temperatures over time at different positions along the Upper Sandia Canyon AU. Specific dates for which data were excluded are reported in Table 5.



Source: LA-UR18-28589

Note: Sub-figures are organized in the direction of flow from Below Outfall 001 to Sandia at Sigma. Horizontal lines represent temperature criteria associated with designated uses (Table 2); green dash = coldwater 6T3 (20°C), orange solid = coldwater TMAX (24°C), and red solid = coolwater TMAX (29°C). High-quality coldwater TMAX of 23°C not shown.

Data were removed from thermograph datasets from periods when thermographs became exposed to air (Table 5).

Figure 3. Water temperature in Upper Sandia Canyon AU, 2014 to 2018

Figure 3 shows that (on an instantaneous basis) water temperatures exceeded the 6T3 criterion for coldwater at every thermograph location during the study period. If data from periods when thermographs were exposed are not considered, the 6T3 criterion for coldwater was not exceeded at Sandia at Sigma between 2016 and 2018, nor at E123 in 2017. The 6T3 criterion was exceeded at E123 in other years, as well as every year at the Below Outfall 001, Below SERF, Below E123, and Sandia at Crossing locations. The coldwater TMAX criterion was exceeded at Below Outfall 001, Below SERF, and E123 at least once during the study period, whereas the criterion was not exceeded any year at Below E123, Sandia at Crossing, and Sandia at Sigma.

The results presented in this section (and Table 5 in particular) show that water temperature statistics in the Upper Sandia Canyon AU are sometimes less than those predicted by the AWTC and sometimes higher. Values were predicted using a regression model (with some amount of model uncertainty), so deviations from actuality were expected. In general, TMAX predictions were biased high (with few exceptions) relative to actual values, whereas 6T3 predictions were more balanced overall with possible temporal and spatial trends.

Lower-than-expected water temperatures, particularly at stations downstream of E123, may have resulted from shading in canyon bottoms and effluent discharged from Outfall 001 that was cooler than the modeled water temperature for the Upper Sandia AU (see Section 6.2). Data from PRISM and LANL MET stations represent temperatures on top of the Pajarito Plateau rather than within Sandia Canyon, so possible effects of shading and microclimate (e.g., cooler, denser air settling in the canyon bottom) seem reasonable when comparing the air and water temperature lines of evidence (Tables 3 and 5). The difference between predicted and actual water temperatures was greater downstream of E123 than upstream, suggesting that these microclimate or hydrologic cooling effects become greater as the canyon narrows and becomes steeper farther downstream.

Cooling over time could be related to the installation of the GCS in 2013, which has led to greater retention of water and vegetative growth in the 0.4-mile wetland reach above E123. Vegetation in the wetlands provides a shading effect, potentially keeping waters cooler throughout the day. A survey conducted between 2014 and 2017 indicated a high density of vegetation within the wetland, increasing wetland plant diversity and tree canopy, and an annual increase in the areal extent of the wetland (LA-UR-21-28841). The GCS also forces alluvial groundwater to resurface before exiting the wetland, which might contribute to cooler water temperatures at E123.

Table 5. Measured and predicted water temperature thresholds, 2014 to 2018

Thermograph	Year	Actual TMAX (°C)	Predicted TMAX (°C) ^a	Actual 6T3 (°C)	Predicted 6T3 (°C) ^a	Designated Use Attained	Dates Exposed/Data Excluded
Below Outfall 001	2014	<u>23.9</u>	27.4	23.9	22.6	coldwater	7/7 to 7/9, 7/31 to 8/7
	2015	<u>23.9</u>	26.2	23.9	21.7	coldwater	6/1 to 6/17, 7/3 to 7/7, 7/15 to 7/21, 7/29 to 8/3
	2016	29.1	30.8	29.1	26.2	warmwater	none
	2017	<u>22.9</u>	28.5	22.9	24.0	coolwater	none
Below SERF	2014	24.7	27.4	24.7	22.6	coolwater	7/7 to 7/9
	2015	25.4	26.2	25.4	21.7	coolwater	none
	2016	25.2	30.8	25.2	26.2	coolwater	none
	2017	<u>23.6</u>	28.5	23.6	24.0	coolwater	none
E123	2014	30.1	27.4	30.1	22.6	warmwater	none
	2015	26.8	26.2	26.8	21.7	coolwater	none
	2016	<u>23.3</u>	30.8	23.3	26.2	coolwater	none
	2017	<u>21.4</u>	28.5	<u>no exceedance</u>^b	24.0	coldwater ^c	none
Below E123	2016	<u>23.5</u>	30.8	23.5	26.2	coolwater	none
	2017	<u>23.2</u>	28.5	23.1	24.0	coolwater	none
	2018 ^d	<u>22.6</u>	28.9	22.3	24.4	coolwater	7/17 to 7/25
Sandia at Crossing	2018	<u>22.1</u>	28.9	22.1	24.4	coolwater	7/10
Sandia at Sigma	2016	<u>20.4</u>	30.8	<u>no exceedance</u>^b	26.2	high-quality coldwater ^c	none
	2017	<u>20.0</u>	28.5	<u>no exceedance</u>^b	24.0	high-quality coldwater ^c	none
	2018	<u>21.0</u>	28.9	<u>no exceedance</u>^b	24.4	high-quality coldwater ^c	7/6 to 7/9

Green shaded cells indicate water temperatures that exceed the coolwater thresholds specified in Table 2.

Bold underlined text indicates water temperatures that meet the coldwater criteria specified in Table 2.

^a Predicted thresholds based on AWTC (Table 3, Equations 1 and 2).

^b In locations where and years when the coldwater use-specific 6T3 threshold was never exceeded, a 6T3 value was not calculated. This is what is meant by "no exceedance."

^c High-quality coldwater attainment depends in part on the 4T3 criterion. The criterion was exceeded at E123 in 2017 (21.4°C) but never at Sandia at Sigma.
4T3 – water temperature not to be exceeded for 4 or more consecutive hours in a 24-hour period on more than 3 consecutive days
6T3 – water temperature not to be exceeded for 6 or more consecutive hours in a 24-hour period on more than 3 consecutive days
AWTC – air-water temperature correlation
TMAX – maximum water temperature

Measured water temperatures and AWTC-modeled water temperatures indicate that, with the exception of some years and locations, the coolwater use is attainable across the entire AU. It is assumed that the cooling will be sustained and that a coolwater designated use is representative of future conditions. The effect of global climate change will have to be evaluated periodically in the future, because it could change the use designations based on temperature.

6.2 MAXIMUM WEEKLY AVERAGE WATER TEMPERATURES

Maximum weekly average (water) temperature (MWAT) values were used to predict the attainable use based on the AWTC Model (NMED 2011a). The NMED SWQB developed a statewide correlation in 2011 showing that ATEMP from PRISM data directly correlated to MWAT. According to the AWTC model, the attainable water MWAT equals ATEMP for locations where water temperature is controlled by ambient air temperature in streams that are not significantly influenced by groundwater (NMED 2011a). As noted in Section 5.1, there is the potential for groundwater and microclimate effects in the Upper Sandia Canyon AU, so the assumption that ATEMP equals MWAT may be invalid in this instance. Therefore, the equations from NMED (2011a) that rely on MWAT directly (Equations 3 and 4) can be used instead of those that rely on ATEMP (and the assumption of its equivalency to MWAT). By inputting measured MWAT values into Equations 3 and 4, the 6T3 and TMAX values that should be observed in the Upper Sandia Canyon AU can be more accurately estimated.

$$6T3 = 1.0346 \times MWAT + 1.3029 \quad \text{Equation 3}$$

$$TMAX = 1.0661 \times MWAT + 4.9547 \quad \text{Equation 4}$$

To calculate MWAT values for the six monitoring locations (i.e., those listed in Table 5), 15-minute thermograph measurements were averaged over each day, and then 7-day rolling averages were calculated over each monitoring year. Data gaps exist where thermographs were exposed to the air (entire days) (Table 5) or when data were being downloaded (short periods during single days). Daily averages were calculated when there were small data gaps during a day (from downloading data) but were not calculated for days when thermographs were exposed to air. Rolling averages were only calculated for full seven-day periods, so these values did not include data gaps. This approach led to significant uncertainty for the 2015 period at the Below Outfall 001 thermograph, which was frequently exposed to the air, thus, no MWAT was calculated for 2015. Table 6 reports the MWAT values, which vary spatially and temporally and range from 16.64°C at Sandia at Sigma in 2017 to 22.35°C at Below Outfall 001 in 2016.

Table 6. Measured MWAT and predicted 6T3 and TMAX criteria

Location	Year	Measured MWAT (°C)	Predicted 6T3 (°C) ^a	Predicted TMAX (°C) ^a	Predicted Attainable Use
Below Outfall 001	2014	21.39	23.44	27.76	coolwater
	2015	nd ^b	nd ^b	nd ^b	nd ^b
	2016	22.35	24.43	28.78	coolwater
	2017	20.95	22.98	27.29	coolwater
Below SERF	2014	20.67	22.69	26.99	coolwater
	2015	21.15	23.19	27.50	coolwater
	2016	21.22	23.26	27.58	coolwater
	2017	20.18	22.19	26.47	coolwater
E123	2014	20.36	22.37	26.67	coolwater
	2015	19.35	21.32	25.59	coolwater
	2016	18.61	20.56	24.80	coolwater
	2017	17.87	19.79	24.00	coolwater
Below E123	2016	19.29	21.26	25.52	coolwater
	2017	18.88	20.84	25.09	coolwater
	2018	17.92	19.84	24.06	coolwater
Sandia at Crossing	2018	19.19	21.16	25.41	coolwater
Sandia at Sigma	2016	17.90	19.82	24.04	coolwater
	2017	16.64	18.52	22.70	coldwater
	2018	18.05	19.97	24.19	coolwater

^a The 6T3 and TMAX values were predicted by inputting measured MWAT into Equations 3 and 4, respectively.

^b MWAT values were not determined for Below Outfall 001 in 2015 because of frequent periods of exposure of the thermograph to air resulting in large data gaps and excessive uncertainty in the MWAT calculation.

6T3 – water temperature not to be exceeded for 6 or more consecutive hours in a 24-hour period on more than 3 consecutive days

MWAT – maximum weekly average (water) temperature

nd – not determined

TMAX – maximum water temperature

The attainable uses were predicted by inputting MWAT values into Equations 3 and 4 and then comparing the output to temperature criteria for designated uses (Table 2). Analysis of the MWAT data suggests that the coolwater aquatic life use is typically attainable for the Upper Sandia Canyon AU with a single exception, Sandia at Sigma in 2017 (Table 6). This analysis provides another line of evidence supporting a coolwater aquatic life use, although, because it relies on modeling temperature criteria, it is not as strong a line of evidence as that presented in Section 6.1.

6.3 OUTFALL 001 EFFLUENT WATER TEMPERATURES

Hourly Outfall 001 effluent water temperature data were available for the summer months from 2015 to 2018 (LA-UR-18-30926). Relative to instream temperatures, effluent temperatures have low variability over time. TMAX and 6T3 values calculated for that time period (Table 7) generally exceeded the 6T3 coldwater aquatic life criterion (Table 2). However, the maximum criterion was exceeded only once, in 2016, when air temperatures were relatively warm (Table 3).

Table 7. Calculated Outfall 001 water temperature thresholds, 2015 to 2018

Year	TMAX (°C)	6T3 (°C)
2015	23.2	23.2
2016	24.6	24.6
2017	22.3	22.3
2018	22.5	22.2

Source: LA-UR18-30926

6T3 – water temperature not to be exceeded for 6 or more consecutive hours in a 24-hour period on more than 3 consecutive days

TMAX – maximum water temperature

TMAX and 6T3 values for Outfall 001 (Table 7) were often similar to or less than those from downstream thermographs (Table 5). These data indicate that natural air temperatures in the Upper Sandia Canyon AU cause instream water temperatures to be warmer than those in discharge from Outfall 001 in the summer.

7 Threatened and Endangered Species, Critical Habitat and Aquatic Life

An evaluation was conducted of the potential impact of proposed water quality changes on Endangered Species Act-listed threatened and endangered species located within Upper Sandia Canyon. Documentation of the presence or absence of threatened and endangered species and critical habitat in Upper Sandia Canyon was analyzed per LANL's habitat management plan (HMP) (Hathcock et al. 2017). The HMP is a comprehensive plan that balances current operations at the Laboratory and future development within the habitats of listed species. The following federally listed threatened or endangered species currently have site plans at the Laboratory: Mexican spotted owl (*Strix occidentalis lucida*), Jemez Mountains salamander (*Plethodon neomexicanus*), and southwestern willow flycatcher (*Empidonax trailii extimus*). The lower section of the Upper Sandia Canyon AU is within delineated habitat for the Mexican spotted owl. Based on a review of the proposed work, the UAA work scope is within the framework of the HMP, so no further consultation is needed. Changes to the water quality designation are also within the framework of the HMP, requiring no further consultation.

Several aquatic life surveys have been conducted in Sandia Canyon (LANL 2017). Fish have not been observed in the Upper Sandia Canyon AU, despite attempts to survey them, indicating that fish are not present. Aquatic life surveys have shown that benthic invertebrate species (macrofauna and meiofauna) are present and diverse: 86 taxa, the majority of them insects, were observed in 2017 (Appendix B);¹⁴ 35% were chironomid midges and 19% were coleopterans (beetles), ephemeropterans (mayflies), or trichopterans (caddisflies). Small meiofaunal species (e.g., tardigrades) accounted for a limited portion of observed taxa. Observed taxa richness did not clearly increase with distance from Outfall 001 (Table 8).

Table 8. Count of taxa observed in 2017 Upper Sandia Canyon

Reach	Reach Description	No. of Unique Taxa
1	uppermost: near forks confluence (gages E121 and E122)	33
2	upper: above wetland	59
3	middle: below wetland (near E123)	37
4	lower: midway between wetland and Sigma Canyon	47
All	Reaches 1, 2, 3, and 4	86

Note: The taxa observed in each reach are not mutually exclusive, so the sum of observed taxa is not equivalent to the total unique taxa observed among all reaches.

¹⁴ Taxa overlap in some cases (e.g., "Annelida" was listed as a unique taxon in addition to Tubificidae, Enchytraeidae, and Lumbricina [among others], all of which are annelid taxa), so the total of 86 species may be an overestimation of species richness.

The benthic macroinvertebrate and meiofaunal species observed during the aquatic life surveys were compared to sensitive and protected species listed by the New Mexico Department of Game and Fish (NMDGF) and USFWS to determine if threatened or endangered species have been found in Upper Sandia Canyon AU (Table 9). Review of the data revealed that no species listed as threatened or endangered by NMDGF and USFWS or discussed in Hathcock et al. (2015) and Hathcock et al. (2017) were found within the Upper Sandia Canyon AU during these surveys.

Table 9. Threatened and endangered aquatic invertebrate species in New Mexico

Species	Endangered	Threatened	State Listed	Federally Listed
Socorro isopod (<i>Thermosphaeroma thermophilum</i>)	X	--	X	X
Noel's amphipod (<i>Gammarus desperatus</i>)	X	--	X	X
Diminutive amphipod (<i>Gammarus hyalleloides</i>)	X	--	X	X
Texas hornshell (<i>Popenaias popeii</i>)	X	--	X	X
Koster's springsnail (<i>Juturnia kosteri</i>)	X	--	X	X
Alamosa springsnail (<i>Tryonia alamosae</i>)	X	--	X	X
Chupadera springsnail (<i>Pyrgulopsis chupaderae</i>)	X	--	X	X
Socorro springsnail (<i>Pyrgulopsis neomexicana</i>)	X	--	X	X
Roswell springsnail (<i>Pyrgulopsis roswellensis</i>)	X	--	X	X
Pecos assiminea snail (<i>Assiminea pecos</i>)	X	--	X	X
paper pondshell (<i>Utterbackia imbecillis</i>)	X	--	X	--
Wrinkled marshsnail (<i>Stagnicola caperata</i>)	X	--	X	--
Florida mountainsnail (<i>Oreohelix florida</i>)	X	--	X	--
Lake fingernail clam (<i>Musculium lacustre</i>)	--	X	X	--
Swamp fingernail clam (<i>Musculium partumeium</i>)	--	X	X	--
Long fingernail clam (<i>Musculium transversum</i>)	--	X	X	--
Lilljeborg's pea clam (<i>Pisidium lilljeborgi</i>)	--	X	X	--
Sangre de Cristo pea clam (<i>Pisidium sanguinichristi</i>)	--	X	X	--
Gila springsnail (<i>Pyrgulopsis gilae</i>)	--	X	X	--
Pecos springsnail (<i>Pyrgulopsis pecosensis</i>)	--	X	X	--
New Mexico springsnail (<i>Pyrgulopsis thermalis</i>)	--	X	X	--
Star gyro (<i>Gyraulus crista</i>)	--	X	X	--
Shortneck snaggletooth (<i>Gastrocopta dalliana dalliana</i>)	--	X	X	--
Ovate vertigo (<i>Vertigo ovata</i>)	--	X	X	--
Hacheta Grande woodland snail (<i>Ashmunella hebardi</i>)	--	X	X	--
Cooke's peak woodland snail (<i>Ashmunella macromphala</i>)	--	X	X	--
Mineral creek mountain snail (<i>Oreohelix pilsbryi</i>)	--	X	X	--

Species	Endangered	Threatened	State Listed	Federally Listed
Dofia Ana talussnail (<i>Sonorella todseni</i>)	--	X	X	--

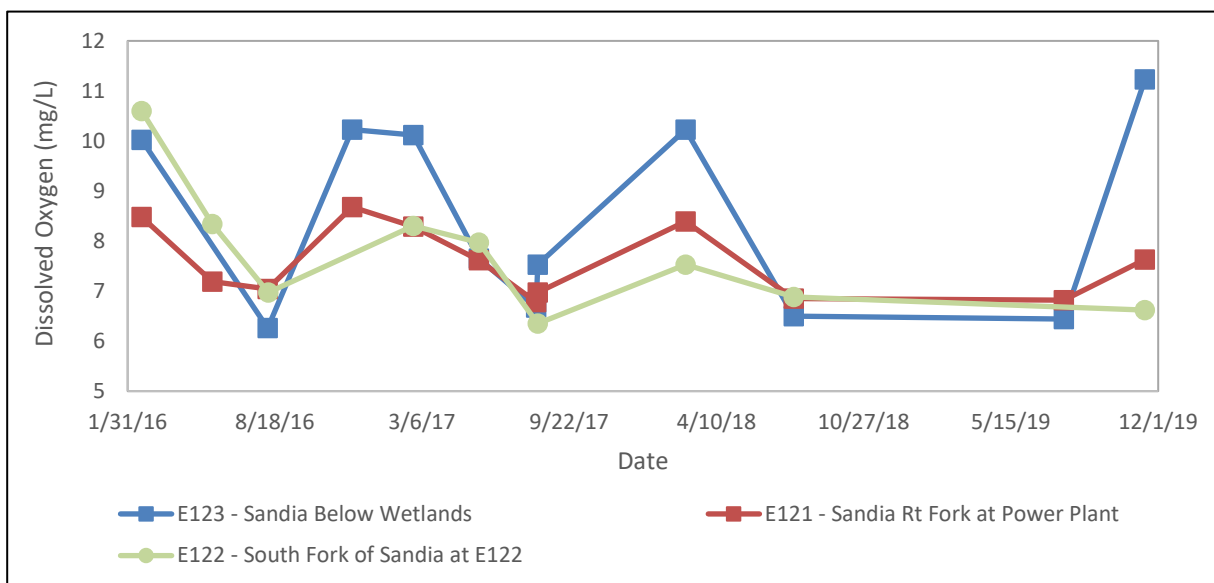
8 Evaluation of pH, Dissolved Oxygen

This section provides a discussion of other factors discussed in the UAA Work Plan (LANL 2020) that may affect attainment of the coldwater aquatic life designated use.

In accordance with LANL (2020), dissolved oxygen (DO) and pH data from LANL's environmental surveillance gages E121, E122, and E123, located within the Upper Sandia Canyon AU, were evaluated to determine whether DO and pH fell within acceptable levels during the monitoring period. The criteria applicable to the coldwater aquatic life designated use are DO ≥ 6.0 mg/L, pH between 6.6 and 8.8, 6T3 temperature $< 20^{\circ}\text{C}$, and maximum temperature $< 24^{\circ}\text{C}$ (§20.6.4.900.H(2) NMAC) (NMED 2011c).

DO and pH data were collected pursuant to LANL's interim facility-wide groundwater monitoring plan (LANL 2016). Data from 2016 to 2019 were downloaded from the Intellus New Mexico website (Intellus 2019). Sampling locations in the Intellus database corresponding to gages E121, E122, and E123 are "Sandia right fork at Pwr Plant," "South Fork of Sandia at E122," and "Sandia Below Wetlands," respectively.

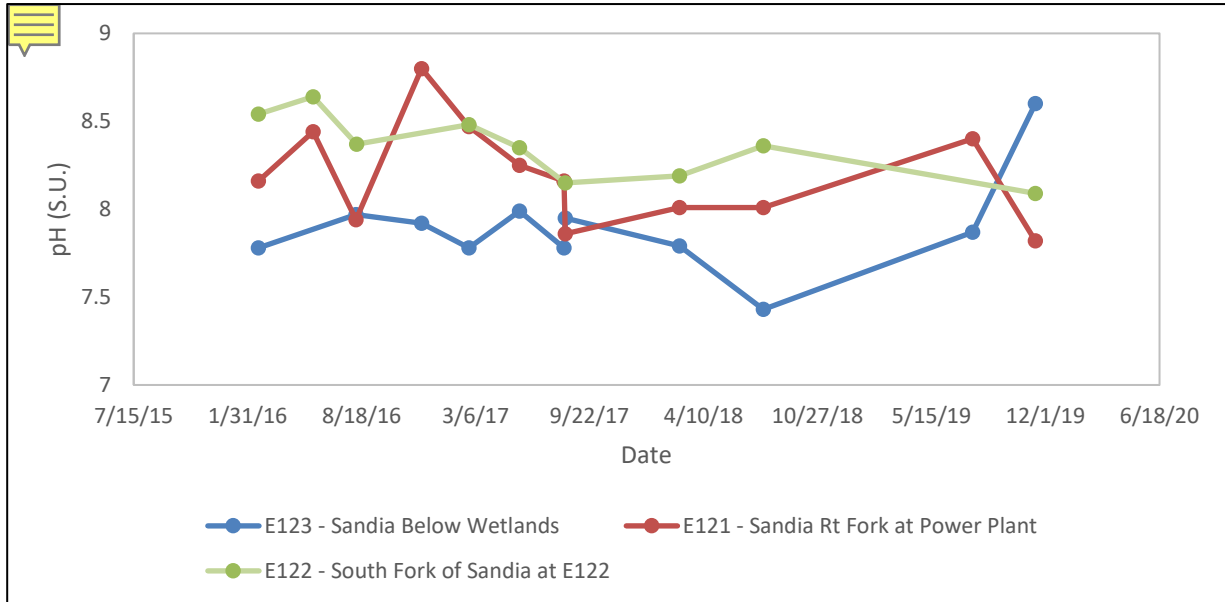
Figure 4 shows DO concentrations at E121, E122, and E123. During the period from 2016 to 2019, DO ranged from 6.26 to 11.23 mg/L, exceeding the criterion limit for coldwater designated use. DO concentrations vary seasonally, with the highest concentrations during winter months. The elevated DO concentrations in winter reflect the greater solubility of oxygen in cold water than in warmer summer water.



Note: Coldwater aquatic life designated use criterion for DO is 6 mg/L.

Figure 4. DO concentrations in Upper Sandia Canyon AU, 2016 to 2019

Figure 5 shows the pH concentrations in the Upper Sandia Canyon AU from 2016 to 2019. During this period, pH concentrations ranged from 7.43 to 8.80, remaining within the coldwater aquatic life designated use range of 6.6 to 8.8. The pH concentrations at E123 were observed to be slightly lower than those at E121 and E122.



Note: The coldwater aquatic life designated use criterion range for pH is 6.6 to 8.8.

Figure 5. pH Concentrations in Upper Sandia Canyon AU, 2016 to 2019

In summary, DO and pH concentrations between 2016 and 2019 were entirely within acceptable levels for the coldwater aquatic life designated use. Therefore, DO and pH do not prevent attainment of the coldwater designated use.

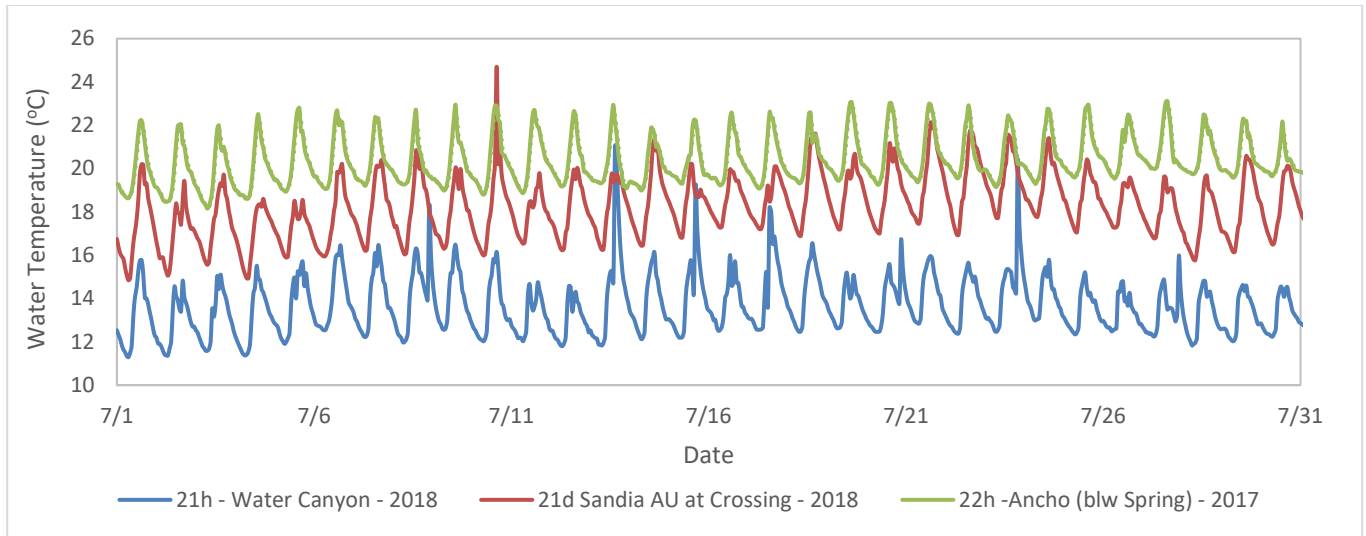
9 Transitional Nature of Ecoregion 21d

Tetra Tech (2010), cited in the 2017 Tecolote Creek temperature UAA (NMED 2017), divided Level IV ecoregions in New Mexico into three sedimentation categories: mountain (21h), foothills (21d), and xeric (22h). This scheme recognizes the differences between high-elevation, steep-sloped, lush-vegetation mountain streams; lower and drier foothills streams; and flatter and still drier xeric streams. The Laboratory lies entirely within these three Level IV ecoregions, and Upper Sandia Canyon falls within ecoregion 21d, which represents a transitional environment between 21h and 22h.

During the 2009 Triennial Review, NMED adopted the coolwater aquatic life designated use into its rulemaking process. The coolwater use criteria are intended to provide appropriate protection to aquatic species in transitional and coolwater areas between high-quality coldwater and coldwater use areas in mountainous streams and warmwater use areas in xeric streams (NMED 2008). Communities living in naturally coolwater streams are tolerant of and adapted to coolwater conditions.

In order to illustrate how the concept of ecoregion relates to Upper Sandia Canyon water temperatures, stream temperatures were measured in three perennial streams located within the Laboratory area: Water Canyon, Upper Sandia Canyon, and Lower Ancho Canyon. These streams are positioned, respectively, in the mountains (21h), foothills (21d), and xeric (22h) landscapes within the Laboratory area, and therefore they span the range of regional conditions for streams with comparable hydrologic regimes.

July water temperatures are plotted in Figure 6, which illustrates increasing temperatures from the mountain region in the west (Water Canyon) towards the xeric region in the east (Lower Ancho Canyon) nearer to the Rio Grande. Temperatures in Upper Sandia Canyon are, on average, between those observed in the other two streams, consistent with expectations for the three ecoregions.



Note: Water, Upper Sandia, and Lower Ancho Canyon monitoring locations are located with ecoregions 21h (mountain), 21d (foothills), and 22h (xeric), respectively, and were sampled in 2018, 2018, and 2017, respectively. Foothills are transitional between mountain and xeric. The coldwater TMAX criterion (24°C) was exceeded once during the 2018 monitoring period in Upper Sandia Canyon; however, this period represents a time (7/10/2018) when the thermograph was exposed to the air (Table 5).

Figure 6. July 2017 and 2018 temperatures for perennial streams within ecoregions 21h, 21d, and 22h

10 AWTC Uncertainty Evaluation

As noted in Section 6.1, the AWTC consistently overpredicted the TMAX statistic (using Equation 2) for the Upper Sandia Canyon AU (Table 5). This section quantitatively evaluates this bias to better understand uncertainty related to the AWTC and air temperatures, allowing for the reconciliation of multiple lines of evidence to strengthen the overall weight of evidence and conclusions regarding attainable use. This analysis expands on Section 6.2, where MWAT values were calculated to better estimate 6T3 and TMAX values and determine attainable uses.

Because the predictions of the AWTC are biased high, either the air temperature data input to the model must be biased high, the water temperature must be biased low, or the AWTC must be inaccurate. However, water temperatures were accurately and appropriately measured in the Upper Sandia Canyon AU according to standard methods by qualified environmental professionals,¹⁵ and based on the thorough analysis of NMED (2011a), the AWTC is assumed to be an accurate representation of the relationship between air and water temperatures in New Mexico. On the other hand, air temperature was not measured in the bottom of Upper Sandia Canyon and (based on the discussion provided in Section 6.1) is expected to be lower in canyon bottoms than on mesa tops (where air temperatures were measured). Therefore, it is reasonable to assume that the bias in AWTC predictions is the result of biased air temperature inputs to the model.

This section investigates how much cooler air would need to be to bring the water temperature predictions into alignment with actual water temperatures (each represented by MWAT); then, this section determines what the attainable use would be given the decrease in air temperatures. If the temperature difference is reasonable and leads to a result consistent with the water temperature line of evidence (Section 6), the weight of evidence can be concluded to support the proposed attainable use.

10.1 UNCERTAINTY EVALUATION APPROACH

In developing the AWTC, NMED (2011a) provided several preliminary equations for predicting MWAT from ATEMP; variations of these models were generated from datasets without relatively cold water data from sites thought to be affected by microclimate or groundwater. Equation 5 is NMED's equation based on all available data (including data from some colder sites); this model is used because it is based on a more robust dataset, includes data from locations that are potentially influenced by microclimate (similar to the Upper Sandia Canyon AU), and is similar to other models presented in the same report. Ultimately, NMED concluded that a 1:1 relationship between ATEMP (based on PRISM) and MWAT was justified for its modeling

¹⁵ Extreme temperature measurements caused by exposure of thermographs to the air were removed to ensure data accuracy.

purposes; for the evaluation presented in this section, the analysis is based on Equation 5 instead of treating ATEMP and MWAT as equivalent. Also, the LANL MET TA-6 monitoring data are used, as that is the local air temperature monitoring station closest to the Upper Sandia Canyon AU (and therefore, a better predictor of air temperature than is PRISM).

$$\text{MWAT} = 0.8675 \times \text{ATEMP} + 2.3758 \quad \text{Equation 5}$$

Where:

ATEMP = average July air temperature

The discrepancy between MWAT predictions and the actual MWAT (Table 10) was addressed by reducing ATEMP values to minimize model error. This was accomplished using Equation 6, which modifies Equation 5 by changing the ATEMP input by an average adjustment value. To minimize model error (i.e., the difference between measured and predicted MWAT), a series of adjustment values was sequentially input into Equation 6, and the model error associated with each adjustment value was calculated. Model error was quantified using the root mean square error (RMSE) statistic. The adjustment value that resulted in the lowest RMSE was selected for subsequent calculations.

$$\text{MWAT} = 0.8675 \times (\text{ATEMP} + \text{adjustment}) + 2.3758 \quad \text{Equation 6}$$

Table 10. Measured and predicted air and water temperature data used for uncertainty evaluation

Monitoring Gage	Year	LANL MET TA-6 ATEMP (°C)	Predicted MWAT (°C)	Measured MWAT (°C)
Below Outfall 001	2014	20.0	19.73	21.39
	2015	19.4	19.21	nd ^a
	2016	22.9	22.24	22.35
	2017	21.4	20.94	20.95
Below SERF	2014	20.0	19.73	20.67
	2015	19.4	19.21	21.15
	2016	22.9	22.24	21.22
	2017	21.4	20.94	20.18
E123	2014	20.0	19.73	20.36
	2015	19.4	19.21	19.35
	2016	22.9	22.24	18.61
	2017	21.4	20.94	17.87
Below E123	2016	22.9	22.24	19.29
	2017	21.4	20.94	18.88
	2018	21.6	21.11	17.92

Monitoring Gage	Year	LANL MET TA-6 ATEMP (°C)	Predicted MWAT (°C)	Measured MWAT (°C)
Sandia at Crossing	2018	21.6	21.11	19.19
Sandia at Sigma	2016	22.9	22.24	17.90
	2017	21.4	20.94	16.64
	2018	21.6	21.11	18.05

^a No MWAT was determined for Below Outfall 001 in 2015 due to excessive uncertainty (Section 6.2).

ATEMP – average July air temperature

LANL MET – Los Alamos National Laboratory meteorological monitoring network

MWAT – maximum weekly average (water) temperature

nd – not determined

After selecting an adjustment value that minimized model errors in predicting MWAT from ATEMP, the 6T3 and TMAX statistics were recalculated using new MWAT values (using Equation 6). Instead of using Equations 1 and 2 to calculate 6T3 and TMAX, NMED's formulation of the AWTC that uses MWAT instead of ATEMP (Equations 3 and 4) was used (NMED 2011a).

10.2 UNCERTAINTY EVALUATION RESULTS

After testing potential adjustment values (20,000 equally spaced numbers between -10 and 10), the adjustment value that minimized model error in Equation 6 (RMSE = 2.1°C) was -1.3°C, which represented a reasonable (i.e., not extreme) reduction in air temperature. This value is the average reduction at all monitoring locations, including those with negligible effects from the wetlands (i.e., Below Outfall 001 and Below SERF). If considering only locations downstream of the wetland (excluding Below Outfall 001 and Below SERF), the adjustment value would decrease to -2.9°C (RMSE = 1.6°C), which would also be reasonable.

The adjustment of -1.3°C was inserted into Equation 6 to calculate revised MWAT predictions (Table 11) for each monitoring year; these predictions apply to the entire AU rather than individual monitoring locations. Predicted MWAT values were then inserted into Equations 3 and 4 to predict adjusted 6T3 and TMAX statistics. Based on the statistics calculated in this way, the designated use criteria would not be exceeded at the coolwater level (Table 2).¹⁶ The coldwater aquatic life designated use is unattainable based on this evaluation. Thus, this evaluation addresses uncertainty associated with the air temperature line of evidence (Sections 4) and brings it into accord with the water temperature line of evidence (Section 6).¹⁷ Therefore, the conclusion in Section 4 that a coolwater designated use is attainable (despite the

¹⁶ The temperature statistics also fall below the marginal coldwater criteria, but marginal designations are reserved for naturally low-flowing streams. Therefore, a marginal coldwater designation would not apply to the perennial portion of the Upper Sandia Canyon AU.

¹⁷ The SSTEMP-based analysis in Section 5 was in general agreement with the water temperature line of evidence in Section 6.

warmwater designated use being attainable in some years and locations) is justified by the analysis presented in this section.

Table 11. Results of uncertainty evaluation

Year	LANL MET TA-6 ATEMP (°C)	Predicted MWAT (°C) (Equation 6) ^a	Predicted 6T3 (°C) ^b	Predicted TMAX (°C) ^b	Attainable Use ^c
2014	20.0	18.56	20.50	24.74	coolwater
2015	19.4	18.04	19.97	24.19	coolwater
2016	22.9	21.08	23.11	27.42	coolwater
2017	21.4	19.77	21.76	26.04	coolwater
2018	21.6	19.95	21.94	26.22	coolwater

^a An adjustment value of -1.3°C was used when predicting MWAT using Equation 6.

^b The 6T3 and TMAX values were predicted using Equations 3 and 4; the predicted MWAT was used as input to those equations.

^c The attainable use is based on a comparison of the predicted 6T3 and TMAX values to criteria in Table 2. Marginal coldwater would not apply to the Upper Sandia Canyon AU because it is a perennial stream reach.
6T3 – water temperature not to be exceeded for 6 or more consecutive hours in a 24-hour period on more than 3 consecutive days

ATEMP – average July air temperature

AU – assessment unit

LANL MET – Los Alamos National Laboratory meteorological monitoring network

MWAT – maximum weekly average (water) temperature

TMAX – maximum water temperature

11 Conclusions

The current designated use for the Upper Sandia Canyon AU is coldwater, with TMAX and 6T3 temperature criteria of 24°C and 20°C, respectively, a DO criterion of 6 mg/L, and a pH range criterion of 6.6 to 8.8. Although the DO and pH criteria are consistently met in the Upper Sandia Canyon AU, the temperature criteria are not. The various analyses of air and water temperature data presented herein indicate that the coldwater aquatic life designated use is unattainable in the Upper Sandia Canyon AU.

Predicted TMAX and 6T3 temperatures from the AWTC model suggest that the designated use that could have consistently been attained across most study years in Upper Sandia Canyon was coolwater (although only warmwater was attainable in some years). Section 5 discusses additional results from the SSTEMP model that support a coolwater attainable use conclusion on the basis of air temperature, as well as watershed geology, hydrology, and meteorology. Sections 6.2 and 10 further justify the conclusion that a coolwater use is attainable by minimizing uncertainty associated with the air temperature line of evidence presented in Section 4.

The conclusion that a coolwater designated use is attainable is well-supported by measured water temperature data analyzed in Section 6. Measured temperatures tend to be lower than predicted by the AWTC downstream of the E123 monitoring location. Table 5 shows that instream water temperatures exceeded the coldwater 6T3 criterion at most thermograph locations during the study period. Similarly, the coldwater TMAX criterion was exceeded at three of six thermograph locations at least once during the study period, and the coolwater TMAX criterion (29°C) was exceeded at two locations during the study period. The 2016 and 2017 TMAX and 6T3 values for E123 were cooler than the values from 2014 and 2015, suggesting a cooling trend below the wetlands. This trend suggests that there could have been a cooling effect from the installation of a GCS in 2013 that resulted in vegetative growth and altered alluvial groundwater hydrology. If the vegetation is creating shade and the shade is responsible for cooling, or if the resurfacing of alluvial groundwater caused by the GCS is responsible for cooling, then a coolwater designated use should be attainable throughout the AU. Shading and microclimate effects, particularly lower in the AU, are also potentially responsible for the lower-than-expected water temperatures.

The analyses provided in this UAA provide multiple lines of evidence, and the overall weight of evidence indicates that the coldest attainable use for the Upper Sandia Canyon AU is the coolwater aquatic life designated use with a TMAX criterion of 29°C. A change in designated use from coldwater to coolwater aquatic life is not expected to impact threatened or endangered species in the vicinity of the Laboratory. The change is also expected to be conservative, given that there were exceedances of the coolwater criterion in some locations and years (based on both estimates from air temperature and measured water temperatures).

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